The Interaction of Wood Species and Wood Quality with the TMP Process—A Review

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ABSTRACT

The nature of fibers in a wood species determines the primary characteristics of pulp quality. Variations within individual species are also important. The effects of wood differences in TMP and other mechanical pulping processes are reviewed and analyzed in this paper.

Wood availability, changes in forestry practices, and pulp quality requirements result in shifts in the raw material supply for pulp mills. Alternative wood species differ in wood density, fiber length and coarseness and other fiber characteristics. The utilization of younger trees, especially plantation grown material, and chipping of tops to a small diameter result in high juvenile type wood in the chip supply. Wood shortages have led to the use of species previously thought to be undesirable such as Douglas fir Jack pine and hardwoods. Other sources of change and variability in chip supply such as, seasonal, chip source (sawmill or whole stem chipping), chip size, age and moisture content and density result in a higher need for process control.

On the other hand, paper grade quality targets and moves to higher value papers put pressures on the pulping system to produce higher quality pulp and modified pulp characteristics especially for LWC and SC paper grades. Wood raw material can significantly affect quality attainment and quality uniformity. Some wood species are inherently more suited for use in particular paper grades but with the correct pulping system and conditions most grades can be made from most softwood species.

Considerable attention has been given to the utilization of hardwoods in mechanical pulping due to their high availability and low cost. In standard TMP and SGW processes hardwoods produce a low quality pulp but high and unique qualities can be produced with chemical treatment.

INTRODUCTION

Historically mechanical pulping has used the various softwood species available throughout the northern hemisphere for raw material. The spruce species in the north, Canada and Scandinavia, and hemlock/balsam fir mixtures on the West Coast have been the major raw materials for mechanical pulping. At a later date use of southern pine was developed in the South. Initially these wood resources were sufficient to supply the needs of mechanical pulp paper grades but as volumes increased pressure was put on these resources and alternative wood species were introduced into the systems.

Southern pine was somewhat of a problem species until development work led to satisfactory processing conditions. West Coast Douglas fir has generally been restricted to use in chemical pulping. Jack pine and larches in the Northeast are problem species that are used to a limited extent. In some areas the available hardwoods are used as raw materials for mechanical pulping. V

This paper reviews the effects of the various wood species in mechanical pulping and discusses differences that are found within species under various growing conditions.

DISCUSSION

Distinguishing Characteristics of Wood

It takes a practiced eye to distinguish one wood species from another in chip form. However the refiner responds differently when processing different wood species and the resulting pulp has significantly different properties.

Trees are classified biologically into two types:

- gymnosperms
- angiosperms.

These are commonly know as:

- softwoods
- hardwoods

They are also termed:

- conifers
- broad leaf or deciduous

These latter terms are imprecise as some conifers, such as the larches, are indeed deciduous; many broad leaf trees are evergreens. Hardwoods differ widely in wood density and hardness from below the ranges of the conifers to very high levels. For example poplars are very low density hardwoods and hickory is high.

The wood in trees consists of a variety of cells:

Tracheids cells are the fibers found in pulp.

Hardwood fibers are short and slender.

Vessels conduct water and nutrients up and down the trunk.

Parenchyma cells (ray cells) conduct materials, in particular resins, radially in the trunk

The tracheid cells are the important ones for papermaking. They are characterized by:

- length
- cross sectional area or coarseness
- cell wall thickness
- length to width ratio

Tracheid cells in trees are arranged longitudinally in the stem. They grow in rows from mother cells in the cambium layer just inside the bark. There is rapid growth in a tree in the spring when water is readily available and temperatures rises. The cells formed at this time have thin cell walls and large lumens, the center of the cells inside the cell wall. As water becomes less available in the summer cell formation slows and the cells formed have thicker walls and smaller lumens, although their overall diameter or width is hardly changed. This difference in cell form between spring and summer results in the visible rings in a cross section of a tree's stem. The two types of material are termed:

- springwood
- summerwood

The various chemical components which form the substance of the cells and particularly the cell walls, are important in chemical pulping but less so in mechanical pulping. They include:

- cellulose
- hemicellulose
- lignin
- resin

In mechanical pulps the nature of the lignin and associated chemicals is important for brightness and bleach response. Resins are important for their detrimental effects in papermaking.

Softwoods are widely used for many pulping purposes and are generally the major source of raw material for pulping. Although not easily classified the various softwood species can be grouped into two types:

1. Those with slender fibers and excellent pulp properties:

    - spruces
    - hemlocks
    - true firs

2. Those with coarse fibers, particularly in the summerwood:

    - pines
    - Douglas fir

The hardwoods have shorter fibers than softwoods and a wide range of wood characteristics. They are somewhat less utilized in mechanical pulping than softwoods but they are becoming more widely used.

Hardwoods can be grouped into three classes for pulping purposes based on wood specific gravity:

- low density
- medium density
- high density

There is also another division, depending upon the way that the vessel elements are dispersed in the cross section of the tree. There are two types:

- ring porous
- diffuse porous.

For mechanical pulping the low density, ring porous species give the best results. The poplar species including aspens, cottonwoods and poplars are most widely used in mechanical pulping.

Mechanical Pulp from Softwood Species

Basic refining characteristics and resulting pulp properties for softwood species are shown in Table 1. Of note are the excellent pulp properties from spruce which has good strength, opacity, brightness and low energy consumption. The West Coast species, hemlock and balsam fir, refine well but result in lower tear and somewhat higher bulk characteristics than spruce. Hemlock is also subject to significant brightness loss with aging in the chip form. Rudie et al have related TMP pulp burst strength to wood density in a range of softwood species and to the differences in wood density between juvenile and mature wood in Loblolly pine (1).

Southern pines proved to be difficult to pulp by mechanical processes but after considerable development work southern pine was utilized in the stone groundwood process, first at the Lufkin mill. Subsequently with the development of the TMP process Southern pine was used successfully at several locations. Higher refining energy is

required to develop a given freeness and strength property. The coarse thick cell wall summerwood fibers of Southern pine require that high rejects rates be used in screening and high rejects refining energy needs to be applied. However satisfactory newsprint and light weight coated papers are made from this resource.

Harris has compared the paper qualities from Northern softwoods, mainly spruce, and from Southern pines. The northern woods tend to give higher opacity and smoother paper surface as would be expected from the high content of coarse fibers in Southern pines (2). Karnis has shown similar results with both surface roughening and linting propensity (3). Comparison of various species studied by Karnis at constant refining energy, constant specific surface development and constant freeness is shown in Figure 1.

Juvenile Wood

Juvenile wood is formed in trees in the center 10-20 rings from the core of the tree. A young tree of 15-20 years consists of mainly juvenile wood but the top of every tree, despite its age, is also juvenile wood. This results in a core of juvenile wood which runs throughout the whole trunk of the tree.

Juvenile wood is characterized by low wood specific density related to the large lumens and thin cell walls of the springwood fibers. The juvenile wood has a high proportion of springwood with very little summerwood. As noted earlier summerwood has thick cell walls and springwood has thin cell walls. In addition to the cell wall thickness juvenile wood has somewhat shorter fiber length. These characteristics are most pronounced in the first 5-10 years of growth then gradually shift to the mature wood type around 15-20 years.

In refining juvenile wood the thin cell wall springwood fibers break down more readily than the thick cell wall summerwood fibers. This results in a pulp with lower strength characteristics and undeveloped coarse fibers. The recommended method of refining juvenile wood is to use low intensity refining which allows separation and development of the strength properties in the thin cell wall fibers. Then the pulp must be screened with high rejects rate to separate the thick wall summerwood fibers for further refining in the reject system which must have sufficient power to undertake this refining. Corson et al have studied the fractionation and re-refining of long fibers in juvenile and mature radiata pine (4).

Further problems with utilization of juvenile wood are its different specific gravity and therefore chip bulk density compared to mature wood, Figure 2 (5) and higher moisture content, Table 2. These differences result in different delivery rates of dry mass to the refiner from the volumetric conveying system typical in a refiner system. If significant quantities of juvenile wood are being utilized by a mill system it is recommended that either separate refining lines be used for the mature and the juvenile wood or an effective mixing system be used to meter constant proportions of the mature and juvenile wood types.

In trials with selected wood from various aged Loblolly pines the author has found higher energy requirement to a freeness target for juvenile wood, Figure 3, but higher burst strength is developed, Figure 4. Tear however was lower in the pulp from juvenile wood.

Control of inflow of juvenile and mature wood has been utilized in several mills. The Tasman Company in New Zealand set up a system of chip piles to allow direction of juvenile and mature woods to the most desirable products (6). A system of three chip piles has been proposed whereby low density juvenile wood is kept in one pile and high density mature wood in another with unclassified material in the third pile (7). If the system is available to draw from these chip piles a blend can be achieved or, alternatively, the chips can be directed to the most suitable utilization.

Sources of juvenile wood include:

- young trees
- tops
- plywood cores

Sources of high density mature wood include:

- sawmills residual chips
- veneer chips

Hatton and Gohal studied the TMP and CTMP pulping of thinnings from various species and found the pulps to be generally acceptable (8). Hardwoods also have a juvenile wood effect. Myers et al studied aspen and found the juvenile wood to have shorter fiber length (0.91 mm compared to 1.12 mm), resulting in lower fiber length in the TMP pulp (0.48 mm compared to 0.55 mm) (9). Tensile and tear strengths were also lower for the juvenile wood.

Juvenile wood is also found in spruce. Wood density and fiber length differences were measured by Brolin et al (10). Tyrvainen has shown that the isolation of sawmill residual chips, old growth stem chips and chips from thinnings could be used to advantage in the production of newsprint and publication papers (11).

Mechanical Pulping of Hardwoods

Hardwoods were initially considered unsatisfactory for mechanical pulping, producing in the stone groundwood and RMP/TMP processes a rather mushy pulp with very short fibers and little strength. Giertz made considerable research on the reasons for this poor performance of hardwoods (12). Initial work concluded that the hardwood pulp's fibers were quite satisfactory and produced good strength properties in combination with the fines from softwoods; however the fines from the hardwood pulp were unsatisfactory, giving poor results, either in combination with the hardwood fibers or with softwood fibers. Giertz concluded that the problem rested in the underdevelopment of the fines and in their lack of bonding potential. He did further work utilizing chemical treatment on the hardwood before refining, either with caustic soda or sodium sulfite; such treatments produced considerable increases in paper strength from hardwoods. Chemimechanical pulping of hardwoods was considered to be an acceptable solution.

Considerable further work has been conducted on the chemimechanical pulping of hardwoods. A recent summary and investigation of the fiber surface characteristics has been made by Cisneros, Williams and Hatton (13).

Sodium sulfite pretreatment of hardwood chips in a CTMP or CMP process results in acceptable pulps. Further work with chemical pretreatment has led to the use of the alkali peroxide pretreatment in the APM or APMP processes allowing the refining of aspen to pulp with properties approaching that of kraft aspen pulp. The chemical treatment, while attaining the improved strength, reduces the opacity from the pulp.

A sodium sulfite CMP pulp is produced at the Massuh SA mill in Argentina from eucalyptus and Georgia-Pacific operated CMP mills at two locations using red alder and mixed beech, birch and maple for use in tissue (14). Currently, aspen is pulped at several BCTMP mills in Canada using either the sodium sulfite or alkali peroxide processes.

One market BCTMP mill produces a range of pulps by varying the species mix of the raw material feed (15). Fiber dimensions of the species available to the mill and other comparative examples are shown in Table 3.

An alternative utilization of hardwoods in TMP processes has been the introduction of up to 25 percent hardwood chips in mixture with softwood. The poplar species and aspens are particularly suited for this mixed refining. Pulp strength properties do not deteriorate up to about the 20-25 percent content of hardwood and thus the raw material resource is considerably enhanced. Opacity and formation can be improved by the use of these hardwood mixtures. Valade et al have reported that up to 30 percent white birch in mixture with spruce in CTMP pulping results in no strength loss (16).

Mixed softwood and hardwood is also utilized in the stone groundwood process to a limited extent. Chemical treatment allows hardwoods to be pulped in the stone groundwood process. In Australia eucalyptus was processed in a stone groundwood system after soaking in caustic soda. The pressure groundwood system was found to perform well on hardwoods with the addition of sodium sulfite solution or alkali peroxide in the shower water.

Aspen is used in Scandinavia using the PGW process to make a specialized publication paper and in North America cottonwood is used for lightweight coated paper production at a southern mill with the PGW process.

CONCLUSIONS

1. In practice most available wood resources can be used in mechanical pulping, although some species, including Douglas fir, larch and Jack pine, should be avoided. V
2. When alternative wood species or different wood properties related to juvenile wood content are present in the wood supply segregation and controlled blending is recommended.
3. Significant opportunities exist in matching the properties available from wood species or juvenile/mature wood differences to specific attributes required in the paper production.
4. In the future, more hardwoods, more juvenile wood and more alternative species will be utilized in mechanical pulping.

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Tables

Table 1

Properties of CTMP Pulp from Various Wood Species

	Black Spruce	South. Pine	Lodge. Pine	Western Hemlock	Douglas Fir
At 100 ml CSF					
Specific En., kWh/ODMT	2150	2795	2365	2050	2475
Burst Index, kPa.m^2/g	3.3	2.1	3.0	2.9	2.7
Tensile Index, Nm/g	49.4	35.6	41.4	42.5	40.4
Tear Index, mN.m^2/g	7.3	6.0	6.9	6.7	6.5
Bulk, cm/g	2.51	2.70	2.65	2.60	2.70
Brightness, TAPPI	63	62	62	60	57
Light Scatter., cm^2/g	490	470	480	490	480

Table 2

Juvenile Wood Moisture Content

Wood Specific Gravity	Typical Moisture Content %	Equivalent Consistency %	Incremental Water Addition %
0.48	52	48	Base
0.43	55	45	13
0.38	58	42	28

Table 3

Fiber Dimensions

	Fiber Length, mm	Fiber Width, um	Wall Thickness, um
Lodgepole pine	3.1	35	2.3
White spruce	3.3	27	1.7
Aspen	1.0	15	2.0
Birch	1.8	17	2.8
Gum	1.7	28	6.2
Maple	0.8	23	1.7
Beech	1.2	19	3.2
Oak	1.4	18	2.5

Figures

Figure 1
Linting Propensity of RMP Pulps

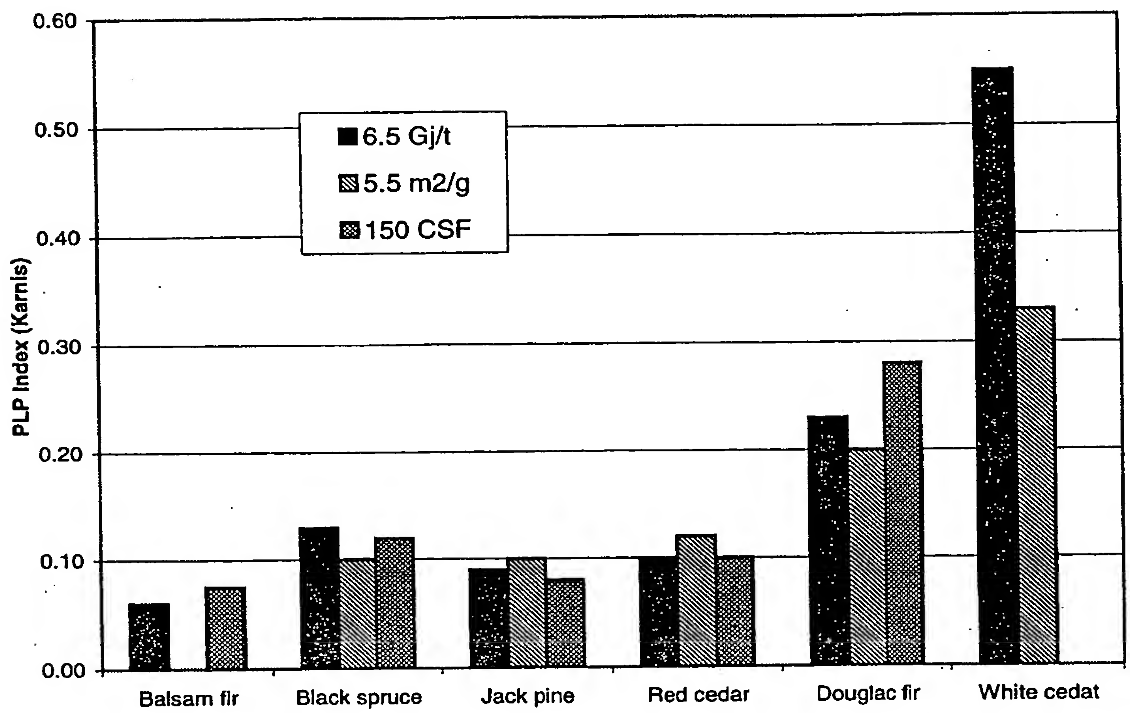

Figure 2
Wood Density to Chip Density Relationship

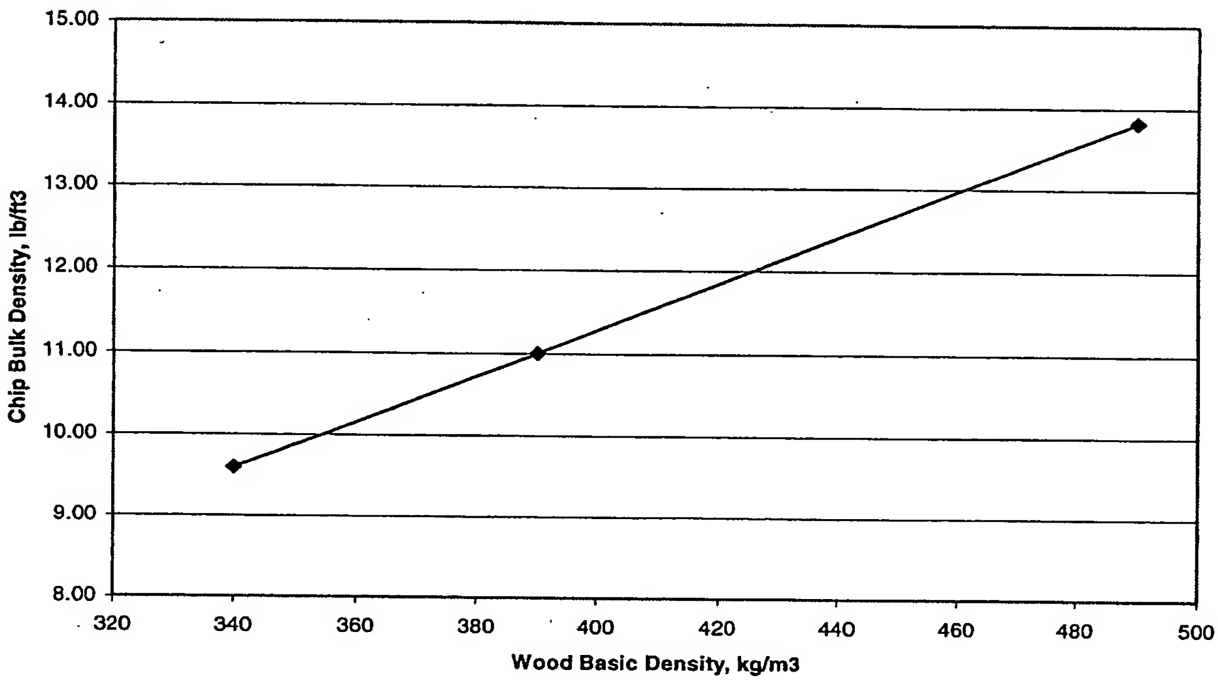

Figure 3
Refining Energy t 100 ml CSF for Lobl lly Pine

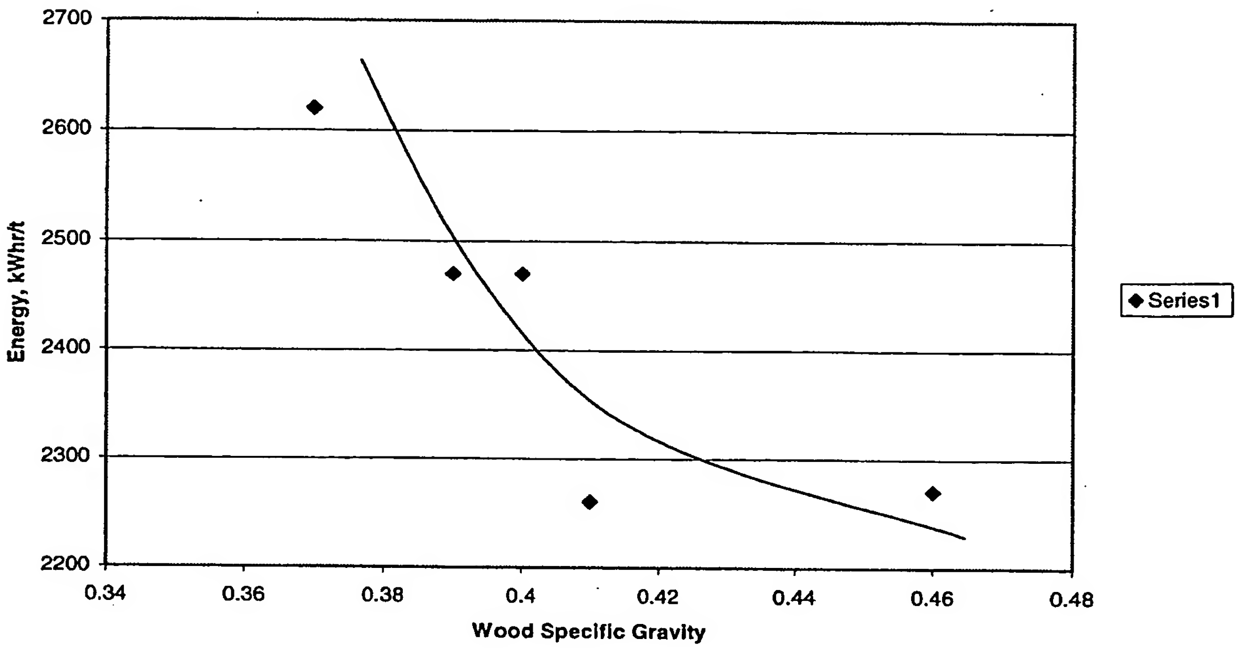

Figure 4
Burst Index at 100 ml CSF for Loblolly Pine